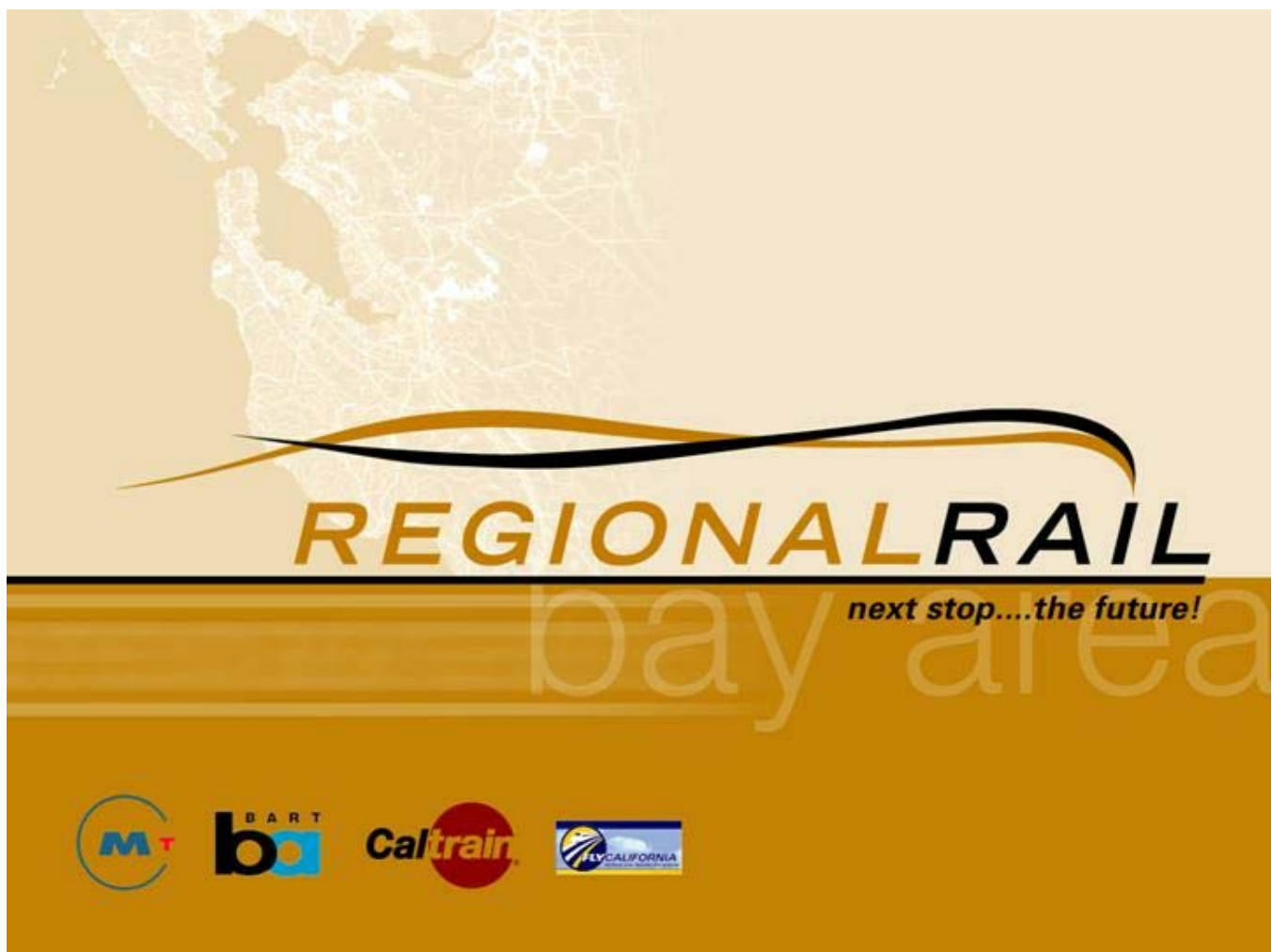


BAY AREA REGIONAL RAIL PLAN

TECHNICAL ANALYSIS OF STUDY ALTERNATIVES

DRAFT Technical Memorandum for Task 4k
Strategic Fleet Planning for the Regional Rail System



June 29, 2007

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STRATEGIC FLEET PLANNING FOR THE REGIONAL RAIL SYSTEM

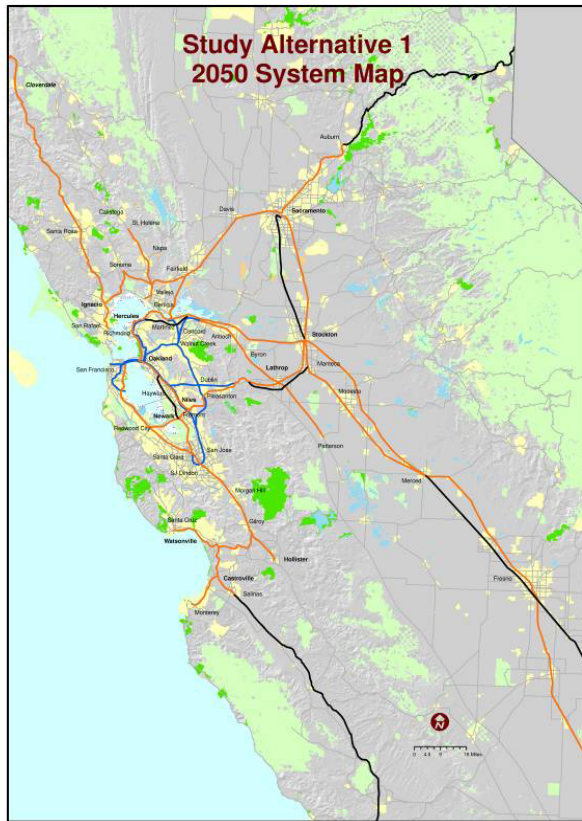
1.0 Introduction

This Technical Memorandum focuses on Task 4k of the work scope for the Bay Area Regional Rail Plan. Specifically, the purpose of Task 4k is to describe and evaluate alternative concepts of rolling stock for use on the various segments of the regional rail system. Developments in vehicle technologies and potential changes in federal regulations suggest a wide range of future options may be available. As such, this technical memorandum identifies and discusses current and emerging technologies available for passenger transportation services on mainline railroad tracks, more specifically as it pertains to the regional rail system in northern California. Order-of-magnitude estimates of fleet requirements also are provided.

Study Alternatives 1 and 2 developed under Technical Memorandum 3b were considered in this analysis (see Figure 1 and Figure 2).

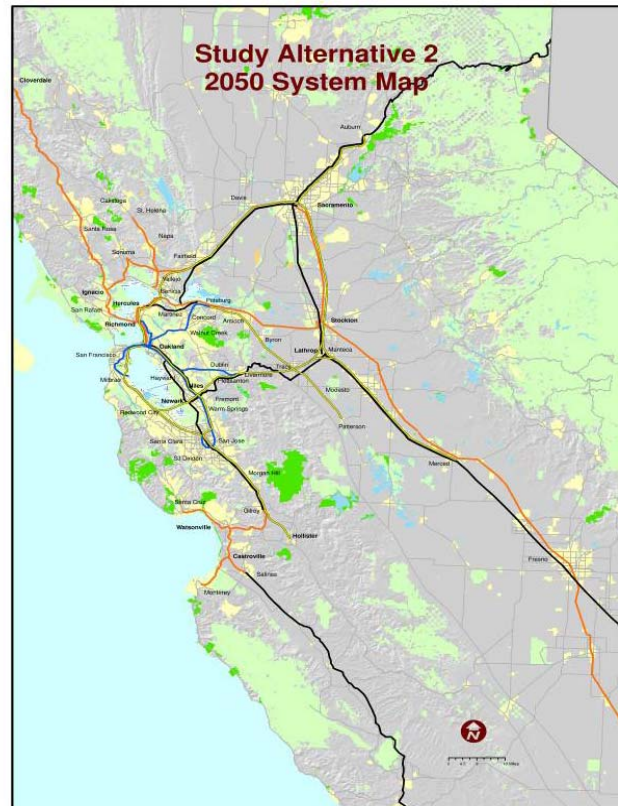
Figure 1: Study Alternative 1

Figure 2: Study Alternative 2



Legend

- HSR only, light weight equipment, double track, fully grade separated
- Regional Passenger Rail, light weight, fully grade separated
- HSR with Regional Passenger Rail
- Freight/Regional Rail
- Predominantly freight, standard equipment
- BART
- Federal Lands
- Park Areas
- Conservation Areas



Legend

- HSR only, light weight equipment, double track, fully grade separated
- Regional Passenger Rail, light weight, fully grade separated
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- Federal Lands
- Park Areas
- Conservation Areas

2.0 Background

Rail rolling stock equipment technologies for passenger services, especially those for operation on the General System of Railways, or mainline railroads, have evolved at a rather slow pace over the last two decades in the United States. There are several factors creating this situation. Among others:

- Most commuter and intercity services use existing tracks, typically owned by private railroads;
- Although some commuter service providers have recently acquired the property on which they operate, the tracks continue to be shared by mixed traffic, namely freight;
- Car floor height interfaces with height of station platforms;
- Most, if not all railroad corridors are typically constrained by:
 - Crossings at grade, affecting power
 - Signal systems restricting speeds to 79 mph
 - Track geometries with limited super elevations, designed for freight train speeds;
- These factors dictate regulations and industry practices which sometimes limits the development and application of technologies;
- Lack of electrification and the cost associated with this system limits the use of motive power to fossil fuel powered equipment. This in turn contributes to increased equipment weight, which then cascades down to reduced performance, such as acceleration and braking, top speeds, and dynamic (P2) forces on rail; and
- No American car builders are left in the U.S. and only one locomotive manufacturer offers a competitive product.

The conditions described above limit the interest on the passenger rail vehicle market and therefore research and development activities. New technologies are generally driven by regulations as opposed to commercial and performance oriented needs, with no incentives to the manufacturers.

2.1 Defining the Problem

The selection of rolling stock equipment for operation on main line railroad tracks is a process that often begins with applying a solution prior to fully understanding the problem. To understand and define the problem is fundamentally important to examine the key issues that will have a serious effect on the services, over the long-term future. Among others, some unique to the conditions and circumstances of the particular project, the following issues must be known and understood:

- **Market Demand** – This is the most fundamental issue that should drive the selection of rolling stock equipment. Market demand will allow to size, not only the trains but also the rest of the system and facilities;
- **Distances and Trip Times** – This factor will guide the level of comfort consistent with competitive trip times;

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- **Capacity** – Rail vehicle technologies are many and varied. Interior space and capacity could be affected by on-board equipment, toilet rooms, and other services and amenities;
- **Passenger Boarding and De-boarding** – The interfacing between car floor and station platform is always a difficult issue given the variety of rolling stock equipment operating on the same tracks, including freight. The Americans with Disabilities Act (ADA) requirements are very strict and must be taken into consideration;
- **Competing Modes** – The ability to provide comparable passenger transportation services by other modes, must also be considered. This applies not only to passenger comfort and safety, but also to overall performance and prices;
- **Ability to Integrate into a Total Transportation Network** – European and Japanese systems have mastered the integration of all transportation modes, including access to airports and other key destination points;
- **Availability of Right-of-Way Sharing and Non-Sharing** – The ability to access and use existing facilities (rights-of-way and railroad tracks) is always a major economic incentive, if capacity and operating protocols permit. If the tracks are shared with other mainline equipment, then the rail vehicles must be compatible in design, construction, and safety performance;
- **Clearances and Constraints** – Available clearances and constraints (geometry, tunnels, grade crossings, etc.) will dictate the maximum size and the dynamic motion of the vehicle;
- **Market Availability** – Most rail vehicle technologies are already well developed in accordance with U.S. Rules, Regulations, and Standards. Two exceptions, namely bi-level electric multiple units (EMU) and diesel multiple units (DMU) find limited market offerings. The only bi-level EMU developed to Federal Railroad Administration (FRA) standards is the gallery-style car built by Nippon-Sharyo for METRA, while the only DMU meeting FRA standards in both bi-level and single-level versions is offered by Colorado Rail Car. While available, diesel and electric locomotives for passenger services may also be included in the category of limited market offering; and
- **Volume of Vehicles** – The number of rail vehicles to be acquired is an issue primarily because of ready availability of the technology and therefore prices, an important consideration when life cycle costing is performed.

A better understanding of the problem can assist in the evaluation and selection of the optimum technologies for the regional rail system.

3.0 Existing Technologies in the Bay Area

There are several types of rail passenger vehicles in use in the Bay Area. This includes trolley/cable cars in San Francisco; light rail vehicles (LRVs) in San Francisco, San Jose, and Sacramento; heavy rail metro used by BART; and standard diesel-locomotives operated by Caltrain, ACE, Capitol Corridor, and Amtrak San Joaquins. A graphic and text definition of the different modes can be seen in the following Figures 3 and 4.



HEAVY RAIL
(Metro, Subway, Rapid Transit,
or Rapid Rail)

Heavy rail service is an electric railway characterized by high-speed and rapid acceleration passenger rail cars operating singly or in multi-car trains on fixed electric rails; separate right-of-way from which all other vehicular and foot traffic are excluded; sophisticated signaling, high platform loading and a heavy passenger volume.



COMMUTER RAIL
(Metropolitan Rail, Regional
Rail, or Suburban Rail)

Commuter Rail is an electric or diesel propelled railway for urban passenger train service of local short-distance travel operating between a central city and adjacent suburbs. Service is provided on regular schedules, moving commuters within urbanized areas and outlying areas. Multi-trip tickets and specific station-to-station fares characterize commuter rail service, with one or two stations in the central business district. Typically uses general railway system operating with mixed traffic (freight, intercity)



LIGHT RAIL
(Streetcar, Tramway, or Trolley)

Light rail is an electric railway with a lighter passenger volume compared to heavy rail with lightweight passenger rail cars operating singly or in short, two-car trains on fixed rails in shared or exclusive right-of-way with low or high platform loading. The vehicle's power is typically drawn from an overhead electric line via a trolley or pantograph.

Figure 3: Passenger Rail Vehicle Mode Definitions

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	Trailer (Unpowered)	Self-Propelled	(Powered)
		Electric	Diesel
S I N G L E L E V E L	 <p>New Jersey Transit "Comet"</p>	 <p>Metro North "M7A"</p>	 <p>Colorado Railcar Prototype</p>
B I L E V E L	 <p>Altamont Commuter Express Gallery Car</p>	 <p>Metra Bi-Level</p>	 <p>TRCX Prototype</p>

Figure 4: Passenger Rail Vehicle Configurations for Commuter Service

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With specific regard to rail vehicle technologies that can operate on the General System of Railways, namely commuter and intercity, with certain exceptions most available technologies currently in use are shown in Figure 4. The following Figure 5 shows the grouping of rail vehicle modes and describes the jurisdictional and governing process.

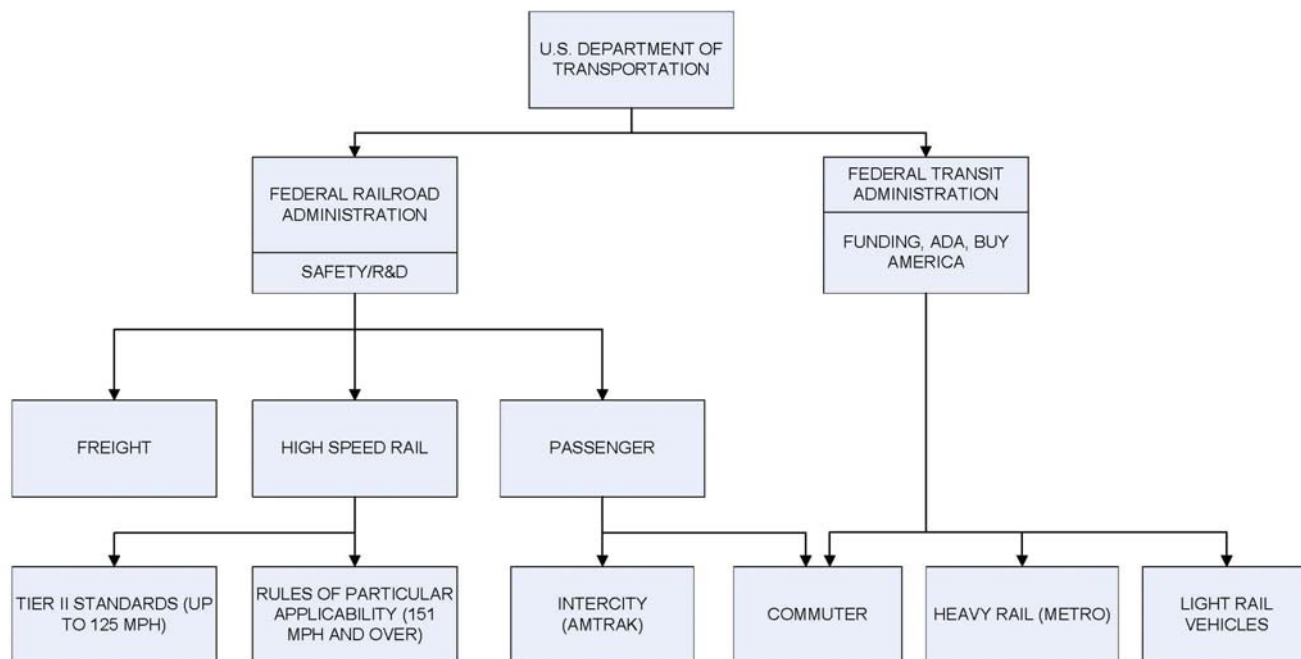


Figure 5: Rail Rolling Stock Safety Regulatory and Jurisdictional System

Within the rail vehicles available for operation on the General System of Railways, technical characteristics include electric and fossil fuel power for locomotives, as well as passenger cars (EMUs and DMUs). In addition, cars can either be bi-level or single level units.

3.1 Bay Area Rapid Transit

Although a heavy rail mode that does not operate on the General System of Railways, the BART system is mentioned because of its relevance in the Bay Area region. The system is even unique in the world of heavy rail given its non-standard rail gauge and the width and height of the cars (Figure 6). In any case, like other heavy rail systems it is fully segregated and separated from other modes and it uses a third rail to collect power from the supply. The only technical regulations applying to the design and construction of the cars affect flammability, smoke, and toxicity of the materials used, especially on the interior and those of the ADA. These vehicles, as is, could not safely operate on the General System of Railways.

In a 2002 feasibility study, BART and the Contra Costa Transportation Authority (CCTA) recommended non-FRA compliant DMU trains that would operate in the median of State Route 4 and then travel southeast to Byron, although this vehicle technology could change over the longer-term. The current project schedule envisions construction starting after 2007 and operations beginning in 2010, with a minimum of seven years for service out to Byron.



Figure 6: BART Train

3.2 Caltrain

3.2.1 Mainline Corridor

Caltrain is a true commuter service, as defined in the U.S., operating on shared railroad tracks and therefore fully under the jurisdiction of the FRA. Caltrain uses multilevel (gallery style) trailer cars hauled by 3000 to 3500 horsepower (HP) diesel-electric locomotives (Figure 7A and 8A). Each car can accommodate up to 140-seated passengers, is equipped with ADA compliant toilets, has control cabs for push-pull operations, and can typically operate at up to 100 mph, when quality of tracks, signals, and motive power allows.

In addition, Caltrain acquired 17 multilevel passenger cars built by Bombardier, for express services (Figure 9). Caltrain can use the same diesel-electric locomotives to operate these cars, although the higher horsepower units can ensure compliance with scheduled trip times.

These vehicles include well-known and developed technologies in the U.S. Multilevel cars are typically being used by operating agencies to increase passenger capacity and shorten train lengths, for accommodating station platform lengths, and better use of available yard space.

Caltrain's current cars and locomotives are designed and built in full accordance with all applicable FRA Rules and Regulations, as well as American Public Transit Association (APTA) Passenger Rail Equipment Safety Standards (PRESS), American Association of Railroads (AAR) Practices and Recommendations, and general industry requirements.

In the future, Caltrain has plans to electrify the mainline corridor between San Francisco and San Jose (Tamien Station). This service would use lightweight electrified multiple-units, which would be non-FRA compliant thereby requiring a waiver from the FRA to operate on the mainline tracks. Bi-level EMUs with a seated capacity of 145 would be needed to accommodate passenger loads on the mainline. Service to Gilroy would continue to be handled with standard FRA compliant equipment shared with freight operations.



The Budd Company has built 399 gallery cars for use in push-pull type passenger service in the Chicago metropolitan area. The term push-pull denotes train operation whereby in one direction the train is operated from the control cab of the locomotive, which pulls the train, and in the reverse direction, the train is operated from a control station in the gallery car at the end of the train, with the locomotive pushing the train. This system eliminates shifting of equipment at terminals, lowers the quantity of cars required, and permits tighter scheduling.



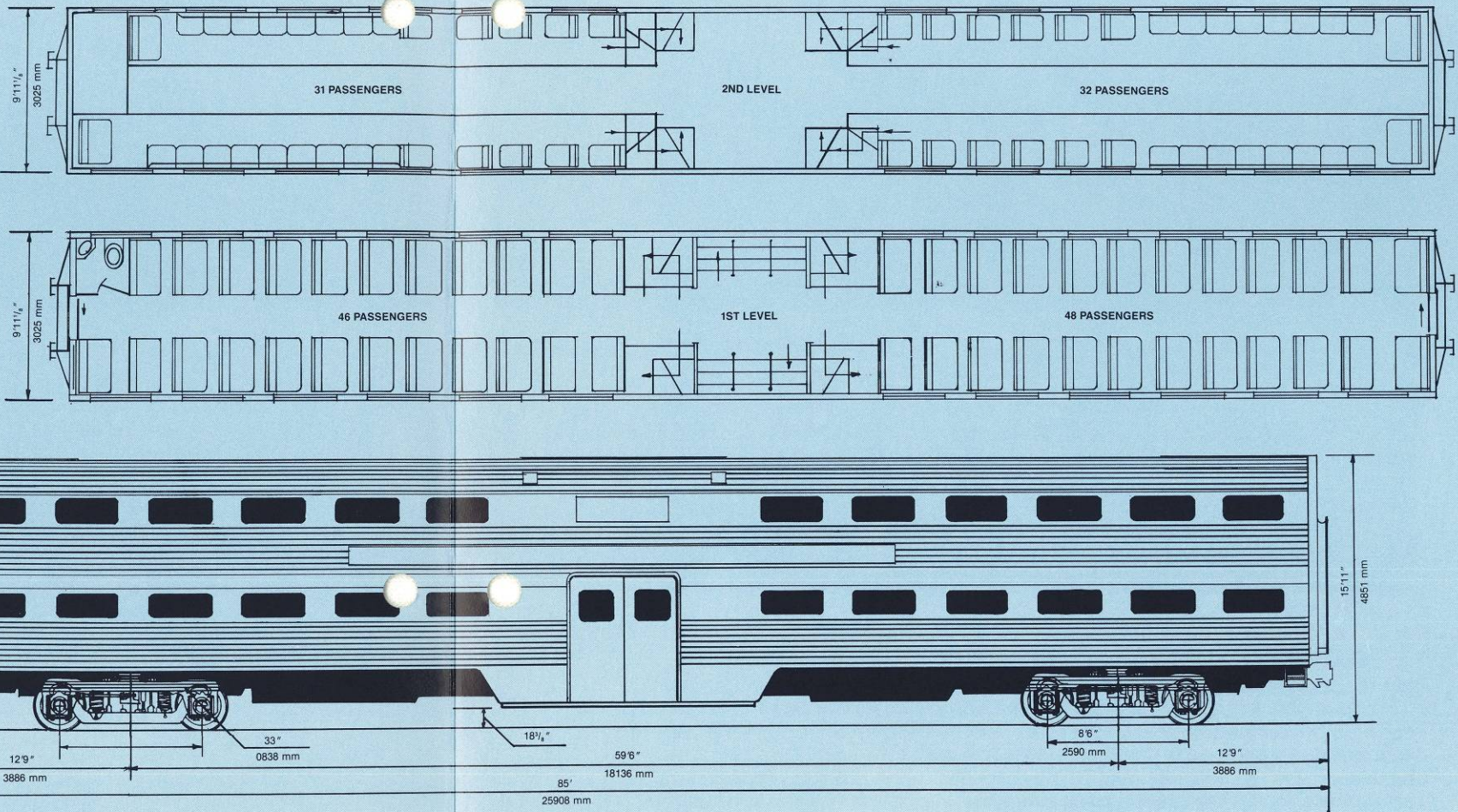
GALLERY CAR

Figure 7.A: Caltrain Original Gallery Car Spec Sheet

GALLERY CAR

SPECIFICATIONS

Length over couplers	Metric	U.S.
Height — rail to roof top	25908 mm	85'0"
Width of car	4851 mm	15'11"
Inside car width	2819 mm	9'3"
Extreme width (over side handholds)	3226 mm	10'7"
Extreme width (over marker lights, where used)	3369 mm	11'5/8"
Extreme width (over sill steps)	2972 mm	9'9"
End platform height above top of rail	1295 mm	4'3"
Track gauge	1435 mm	4'8 1/2"
Approximate car weights (ready to run)		
Car with cab	48.5 MT	107,000 lbs
Car without cab	46.7 MT	103,000 lbs
Seating capacity		
Car with cab—lower level 92, upper level 55, total 147		
Car without cab—lower level 94, upper level 63, total 157		



The Budd Gallery Cars are commuter cars designed to accommodate a variety of situations in operating logistics with a minimum number of different car types. This is accomplished through utilization of two basic designs: the cab car and the trailer car.

The cars are constructed of stainless steel and meet or exceed FRA requirements for compression strength, vertical loading, and collision post strength. All interior surfaces are stainless steel, or melamine-faced plymetal panels, with moulded fiberglass panels around the windows. The cars meet or exceed the latest UMTA guidelines on flame and smoke emission and FRA glazing requirements. Passenger side ingress and egress is via electro-pneumatically operated bi-parting doors located at the center of the car. Manually operated bi-parting doors in the center vestibule provide access to passenger seating areas on each side of the vestibule. Four stairways

from the central vestibule provide access to the upper seating areas. Manually operated sliding end doors provide between car access. Other additional features provide for exit and access to the cars in emergency situations. The seating arrangement has some flexibility with slight variations possible (i.e., two and two walk-over vs. fixed, single fixed on upper level vs. single walk-over, etc.). Fare collection can be accomplished entirely from the lower level. Car heating is electric. Air conditioning is accomplished by two eight-ton units located in the center vestibule ceiling. Fluorescent lighting is used throughout the cars. A retention type toilet, lavatory, and overhead exhaust fan are located in the toilet room at one end of each car. The cars may be optionally equipped with a public address/intercom system, and floor carpeting in lieu of sheet rubber.

The trucks are cast steel, inside swing hanger suspended, two axle with

33 inch wheels, and 6 inch x 11 inch journals, and 16 inch center plate. The trucks meet or exceed FRA and AAR fatigue and safety requirements. The brake system is a schedule 26 system utilizing tread units and modified to suit individual requirements of the operating property. The cars are equipped with Type "H" tight lock couplers.

The cab end of the cab car and the cab itself receive full locomotive treatment. They meet all FRA requirements for adherence to the AAR clean cab concept. The cab exterior is properly equipped with headlights, class lights, rear end marker lights, body mounted pilot and sanding on lead axle, etc. The cab is equipped with a throttle stand, brake stand, speed indicator, horn valve, bell valve, brake gauges, and all other devices required to provide safe, efficient passenger train operation. The cab can be additionally equipped with cab signal and two-way radio if desired.

Figure 8.B: Caltrain Original Gallery Car Spec Sheet



Figure 9: Caltrain Service

Electrification can also be accomplished using electric locomotives designed and built in accordance with U.S. Rules and Standards, such as the ALP 46 unit built by Bombardier for New Jersey Transit (Figure 10) and the high horsepower unit built by Alstom and Bombardier for Amtrak and MARC (Figure 11).



Figure 10: ALP46



Figure 11: MARC High Horse Power Electric Locomotive

3.2.2 Proposed Dumbarton Service

If Caltrain's mainline corridor is electrified, then it would make sense to expand the fleet with similar and compatible equipment for Dumbarton rail service. The Dumbarton service would operate across the south end of the San Francisco Bay to the east side, interlining on the Caltrain mainline tracks. In the near-term, it could operate with standard FRA compliant equipment, with diesel locomotives and cars. Later in the future, dual-powered locomotives could be used, to avoid changing power units for operation on non-electrified territory. Passenger cars, if not EMU's, could be the same for both services, increasing efficiencies. However, the standard cars would require a waiver to run on the electrified Caltrain line. As such, the lightweight non-FRA compliant EMUs could be used instead.

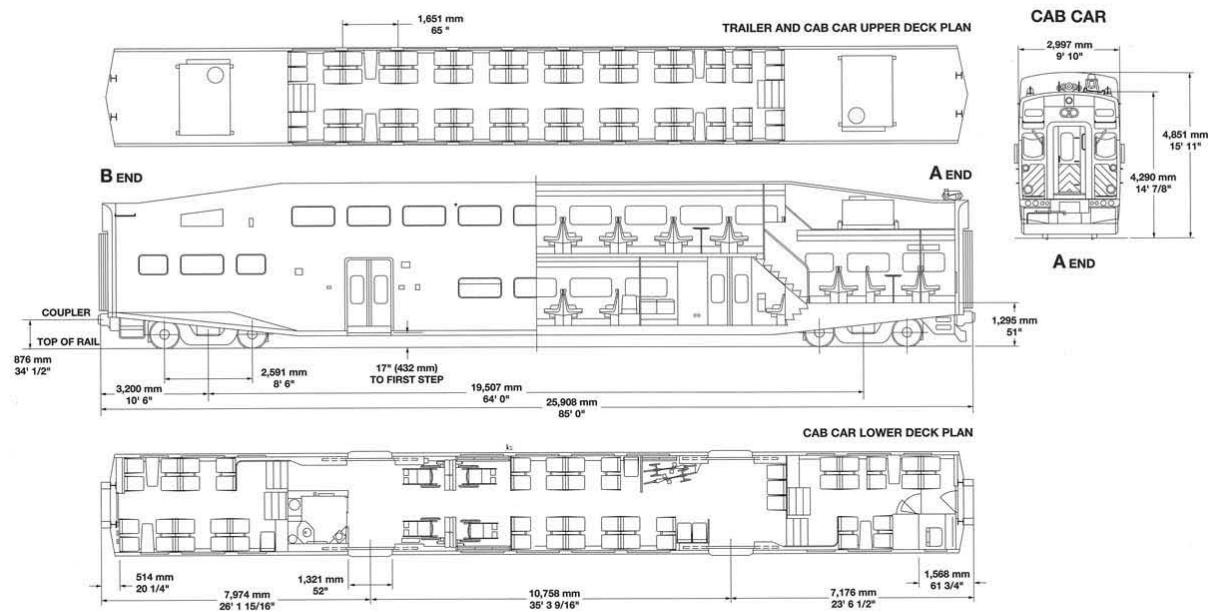
3.3 *Altamont Commuter Express*

The Altamont Commuter Express (ACE) uses similar equipment as Caltrain today, including bi-level cars by Bombardier and diesel-electric locomotives (Figure 12). A certain number of bi-level cars are equipped with control cabs, allowing push-pull operations. As with Caltrain, both cars and locomotives are conventional and proven rolling stock equipment, designed and built in full accordance with all applicable U.S. Standards. ACE will continue to use this standard FRA compliant equipment in the future to accommodate passenger loads and compatibility with freight services.



Figure 12: Altamont Commuter Express

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General Data

Type of vehicle	Bi-Level Commuter Car
Owner	
Operator	Amtrak
Total order	119
Train consist	Up to 10 vehicles

Technical Characteristics

Power supply	480 V, 3 ph, 60 Hz head end power
Low voltage power supply	36 Vdc, nickel-cadmium emergency battery
Auxiliary power supply	Static battery charger and low voltage power supply
Underframe	Low-alloy, high-tensile steel
Superstructure	Aluminum alloy structure and sheathing, painted
Floor	Plymetal covered with carpet or rubber flooring
Doors	Two pneumatically operated two-leaf sliding pocket doors per side, service doors at each end
Side windows	Fixed, tinted double glazed, meeting FRA Type II standards
Fixed seats	Aluminum frames, molded fiberglass with upholstered inserts
Trucks/Bogies	Two per vehicle, cast steel with inboard bearings
Primary suspension	Chevron rubber spring
Secondary suspension	Air spring
Wheelslide protection	Yes
Brakes	Pneumatic tread brakes and disk brakes
Parking brake	Mechanical hand brake
Heating	Electric convection floor heaters, overhead forced air heaters
Air-conditioning	Two self-contained units, one at each end of vehicle
Washroom	One per car, fully accessible
Interior lighting	Fluorescent

Dimensions and Weight

	Metric	Imperial
Length (over couplers)	25,908 mm	85' 0"
Length (over body ends)	25,705 mm	84' 4"
Width (over side sheets)	2,997 mm	9' 10"
Height (rail to roof)	4,851 mm	15' 11"
Height (rail to lower floor)	635 mm	2' 1"
Headroom (center aisle)	2,007 mm	6' 7"
Doorway width	1,321 mm	52"
Doorway height	1,981 mm	6' 6"
Step height (above standard low platform)	254 mm	10"
Step height (above top of rail)	432 mm	17"
Truck centers	19,507 mm	64' 0"
Truck wheelbase	2,591 mm	8' 6"
Track gauge	1,435 mm	56 1/2"
Wheel diameter	838 mm	33"
Aisle width (upper deck)	735 mm	28 15/16"
Aisle width (lower deck)	756 mm	29 3/4"
Empty weight (trailer car)	50,200 kg	111,000 lb
Empty weight (cab car)	51,800 kg	114,500 lb

Performance and Capacity

	Metric	Imperial
Maximum design speed	160 km/h	100 mph
Maximum operating speed	135 km/h	84 mph
Service braking	2.41 km/h/s	1.5 mph/s
Emergency braking	2.90 km/h/s	1.8 mph/s
Minimum horizontal curve radius	76 m	250'
Minimum vertical curve radius	610 m	2,000'
Seating capacity	Cab cars	Trailer cars
- With wheelchairs & bicycles	134	146
- Without wheelchairs or bicycles	142	149
Crush load	360 passengers	

Figure 13: Original ACE Spec Sheet

3.4 Intercity and Intra-State Rail Services

Caltrans provides equipment for intercity and intra-state services, operated by Amtrak. Currently, Amtrak operates three intercity rail services in California:

- Pacific Surfliner -- travels along the southern California coast between San Luis Obispo and San Diego. Southern California travelers have even more options with the Rail2Rail program, Amtrak/Metrolink/Coaster;
- San Joaquins -- runs between the San Francisco Bay Area and Sacramento in the north and Bakersfield in the south, where Thruway motorcoaches connect to southern California destinations; and
- Capitol Corridor -- provides service between the Sacramento region and the Bay Area, with a Thruway connection to San Francisco at Emeryville.

While some services, such as the Capitol Corridor may classify as “long commuters,” all Caltrans cars are similar double deck vehicles, with a passageway between cars at the upper floor. The lower floor providing access to the passengers is at 17 inches from top-of-rail, the lowest on passenger cars operating on mainline railroads in the U.S. This height allows for easy access from an 8-inch station platform, facilitating access for individuals with disabilities. These cars, known as the California cars, are part of the Surfliner fleet (Figure 14). In addition, they are conveniently furnished with comfortable reclining seats for intercity services and locomotives.

Passenger cars include trailers and control cabs, hauled by diesel-electric locomotives. All equipment is designed and built in accordance with applicable U.S. Rules and Standards. These intercity services will continue to use this type of standard FRA compliant equipment in the future, as will the intra-state services shown in Figures 17 and 18.



Figure 14: California Car / Surfliner



CALTRANS CALIFORNIA CAR

The Caltrans California Car is the result of State of California Proposition #116 funding which directed Caltrans to develop specifications and procure standard state-of-the-art passenger cars to be used in intercity and commuter service throughout the State.

The California Car for both intercity and commuter operations uses the same carbody shell, major systems, subsystems and components. It is operationally compatible with other mainline commuter, intercity and interstate equipment. It provides ADA handicapped accessibility to all passenger amenities.

The California Car is designed to promote rail passenger ridership as an attractive alternative to other modes and ultimately be the primary mode in the corridors it services. As designed, the Caltrans car embodies the ideals of state-of-the-art technology, passenger comfort, convenience, safety and efficiency by employing proven technologies from around the world.

THE ORDER

Customer	• Caltrans – California Department of Transportation, Division of Rail
Total order	• 88 Vehicles
Award date	• March 2, 1992
Ship date	• Third Quarter 1993-Fourth Quarter 1994
Type of cars	• Bi-Level, Locomotive hauled • 42 Commuter Trailers • 6 Commuter Cab Cars • 20 Intercity Trailers • 10 Intercity Cab Cars • 10 Intercity Food Service Cars

CAR BODY

Underframe	• Stainless Steel Structure with low alloy, high-tensile end underframes
Superstructure	• Stainless steel structure and sheathing
Floor	• Plymetal with carpeting
Doors	• Two bi-parting, pocket doors per side, pneumatically operated
Side windows	• Fixed and emergency exit windows, double-glazed, tinted glass, FRA II
Seats	• Deluxe cushioned and contoured
Accessibility	• To all amenities • Accessible toilet room, one per car • Ramps or Alternate Power Lifts

SUSPENSION AND BRAKING

Trucks	• Two, cast steel, outside bearing
Suspension	• Nested coil springs primary, coil spring secondary
Truck centers	• 61 feet, 9 inches
Wheels	• Solid, 36 inches
Wheel base	• 8 feet, 6 inches
Track gauge	• 4 feet, 8.5 inches
Service brakes	• Pneumatic friction brake, disc and tread, two per axle, slide control
Parking brakes	• Mechanical handbrakes

Figure 15.A: Original California Car Spec Sheet

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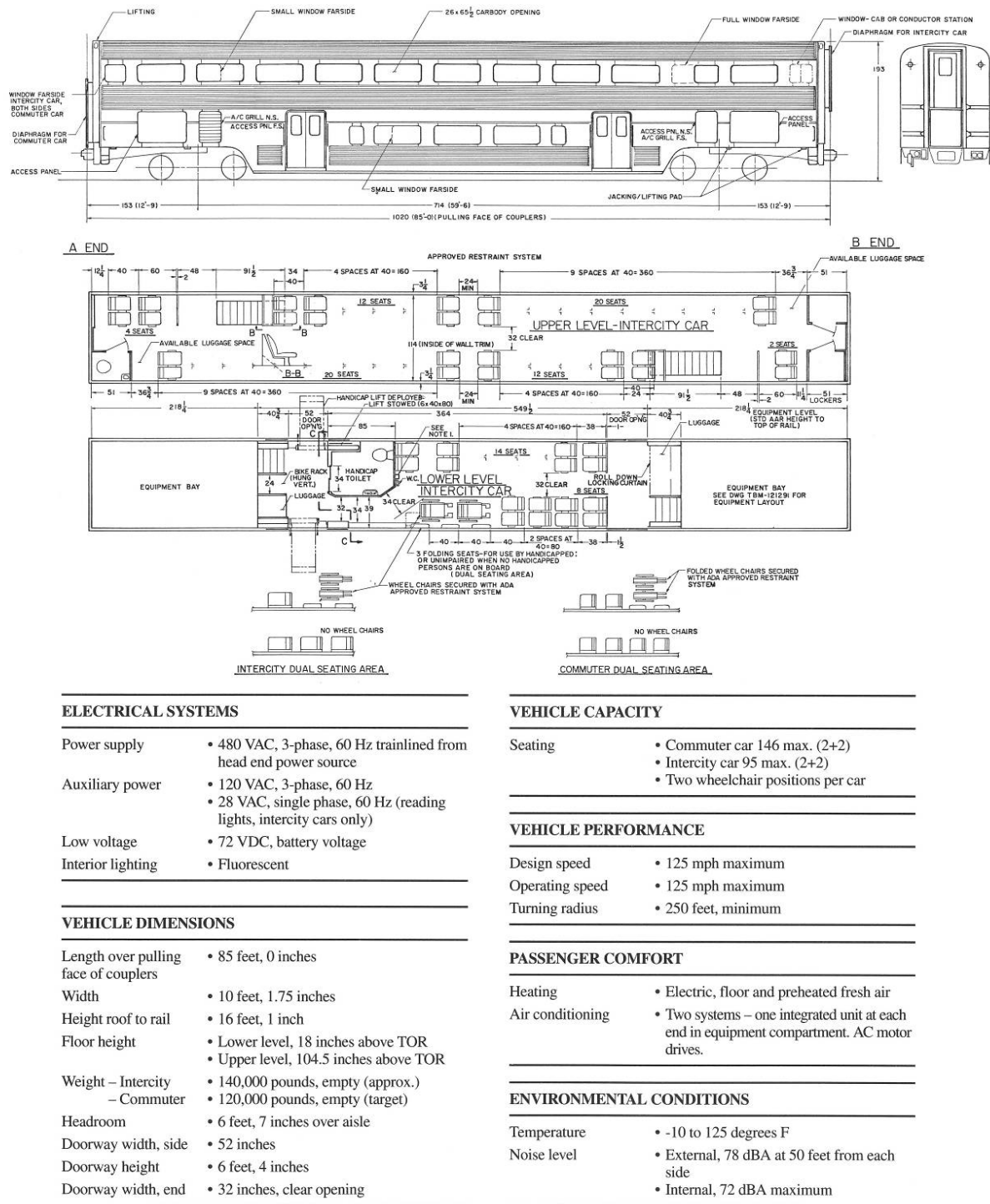


Figure 16.B: Original California Car Spec Sheet



Figure 17: Amtrak Fleet Intra-State Services



Figure 18: Amtrak Superliner Intra-State Services

3.5 Sonoma-Marín Area Regional Transit

The planned Sonoma-Marín Area Regional Transit (SMART) passenger rail service would cover some 70 miles in Sonoma and Marín counties north of San Francisco. FRA compliant diesel multiple units, otherwise known as diesel rail cars are being considered. This technology is used widely abroad and was popular in the U.S. during the 1950's and 60's, when railroads served branch lines. In the course of such operations, DMUs would typically be decoupled from longer passenger trains.

Because of its flexibility to operate as part of a longer conventional train, as well as a single unit, this technology is gaining renewed interest. One of the reasons is that operating economics are more favorable for trains of up to three self-propelled cars than a diesel locomotive hauled train consist of similar length. The economics favor the locomotive hauled train consist when more than three cars are operated.

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The dilemma is that the only available FRA compliant DMU is by Colorado Rail Car, a small manufacturer with severe production limits. Other mass producing manufacturers have expressed interest on this technology, but the lack of substantial orders (30 or more cars) have not resulted on a production series. One manufacturer, Rotem of South Korea, actually came close to delivering 24 FRA compliant DMU cars for North Carolina's Triangle Transportation Authority (Figure 17), but its regional rail project has been delayed due to funding difficulties.



Figure 19: Triangle Transportation Authority

Other non-FRA compliant DMU vehicles operate or will soon operate in New Jersey, Texas, Oregon, and California. Maximum operating speed for these cars is 50 to 60 mph. These “lightweight” DMU designs (Figure 18) are fully developed and popular in European countries, but application on mainline railroad tracks in the U.S. requires a waiver from FRA. While possible, this process is often complicated, and approval is not always certain.



Figure 20: Bombardier Talent DMU

3.6 Freight Rail Equipment

Freight trains currently operate on most, if not all corridors in the Bay Area. Although train lengths vary, all locomotives and cars are designed and constructed in accordance with the same FRA Rules and AAR Standards. This condition also applies to passenger trains sharing tracks and rights-of-ways.

It is conceivable that waivers to the rules may be awarded, under special and very specific circumstances, but this process is not simple. If a new network of rail transportation is developed and a compelling argument put forth, it is possible that FRA will consider viewing it as a system, in which case new technologies may be adapted. However, freight rail operators may not be willing to employ technologies that may not be compatible with the rest of their fleets.

All freight trains in the United States are hauled by diesel-electric locomotives. The two major suppliers for road equipment are General Electric (GE) and EMD (previously EMD-General Motors). Both GE and EMD produce their own diesel engines and electric equipment. The annual market for freight locomotives is for about 1,500 to 2,000 units, obviously much greater than passenger locomotives and therefore more conducive to development investments. Components such as power controls, fuel management systems, and electric drives, coupled to developments for compliance with Environmental Protection Agency (EPA) requirements, contain new technologies developed by the two manufacturers.

GE for instance, is developing a 4400 hp, 207-ton hybrid locomotive, utilizing the energy dissipated during braking. The energy is stored in batteries and uses it when additional power is needed, which reduces emissions and fuel use. Images of latest developments by GE and EMD can be seen in Figures 21 and 22.

Typical freight railroad locomotives are high horsepower units, at 5000 to 6000 hp. These large engines are obviously heavy, requiring six axles in order to maintain acceptable axle loads. The most popular models are equipped with AC drives, enhancing adhesion levels through truck-controlled inverters. These locomotives are not suitable for passenger services.

Because of the six axles and the heavy weight (about 400,000 lbs.), optimum horizontal and vertical track geometries for freight locomotives are not necessarily the optimum for lighter weight, higher speed passenger trains and therein lays the inevitable compromises.

With regard to freight cars, technologies continue to advance, with the primary objective of accommodating specialty cargo, such as containers. The freight car industry is quite adept at responding to the needs of the market reasonably fast, therefore, technologies continue to expand. On the safety side, tank cars are receiving a great deal of attention from the FRA and the industry. As a result, new regulations for design and construction should be expected in the near future.



Figure 21: GE Hybrid Locomotive



Figure 22: EMD SD70Ace Locomotive

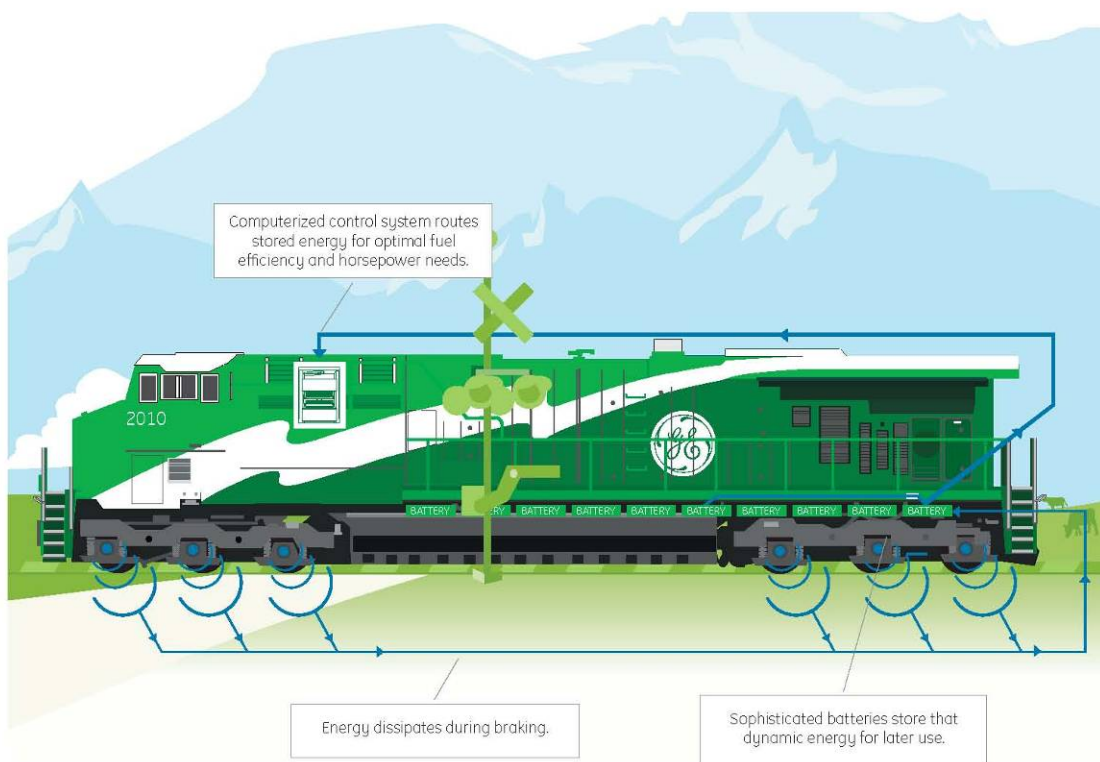
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ecomagination™

Hybrid locomotive

The future of rail is just around the bend.

How do you make a 4,400 horsepower locomotive more environmentally conscious? With pure ecomagination.

GE engineers are designing a Hybrid diesel-electric locomotive that will capture the energy dissipated during braking and store it in a series of sophisticated batteries. That stored energy can be used by the crew on demand—reducing fuel consumption by as much as 15 percent and emissions by as much as 50 percent compared to most of the freight locomotives in use today. In addition to environmental advantages, a hybrid will operate more efficiently in higher altitudes and up steep inclines.



imagination at work

Figure 23.A: GE Hybrid Locomotive Spec Sheet

a product of
ecomagination

Hybrid locomotive

The future of rail is just around the bend.

More information about the hybrid locomotive

GE engineers are developing a hybrid locomotive with the goal of creating the cleanest, most fuel-efficient high-horsepower diesel locomotive ever built.

The energy dissipated in braking a 207-ton locomotive during the course of one year is enough to power 160 households for that year. The hybrid locomotive will capture that dynamic energy and use it to produce more horsepower and reduce emissions and fuel use.

GE's hybrid locomotive's lead-free rechargeable batteries will be able to provide superior performance by allowing operators to draw an additional 2000 horsepower when needed.

Compared to a locomotive manufactured in 2004 (meeting the U.S. Environmental Protection Agency's Tier 1 emission requirements for railroad locomotives), GE's hybrid locomotive is being designed to reduce carbon dioxide emissions over its lifetime as much as taking 2,600 cars off the road for a year.

GE's hybrid locomotive is being designed to emit half as much nitrogen oxide as locomotives built 20 years ago.

Replacing every locomotive in North America manufactured before 2001 with GE's hybrid technology would, in a year, cut nitrogen oxide emissions as much as removing one third of all cars from U.S. roads.

If every locomotive in North America could operate as efficiently as GE's hybrid locomotive is being designed to operate, railroads could achieve a fuel-cost savings of \$425 million dollars each year.



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Figure 24.B: GE Hybrid Locomotive Spec Sheet

BASIC FEATURES EMD SD 70ACe

Engine

- 16-710G3C-T2
- High efficiency turbocharger
- Electronic fuel injection
- Tier-2 emissions certified

AC Traction Technology

- Utilizes truck-controlled IGBT inverters for higher inherent reliability
- Simple, robust motor design
- Extends motor overhaul interval

Gen2 FIRE™ System

- Transreflective LCD color display for enhanced readability
- Provides a single integrated archive for ease of maintenance and troubleshooting
- Based on an open architecture which supports numerous 3rd party applications
- Various wireless communications packages available (Cellular, Wireless LAN, etc) to support [IntelliTrain™](#) and [Locomotive Management Services](#)

HTSC Bolsterless Truck

- Designed for one million miles between overhauls
- Reduce maintenance due to fewer components

Specifications

- Total weight on rails - 408,000 lbs.
- Height - 15'11"
- Overall length - 74'3" ft.
- Fuel capacity - 4,900 gal.
- Lube oil capacity - 420 gal.
- Cooling water capacity - 275 gal.

Cab Features

- Three seat crew arrangement
- Ergonomic workstation
- Increased leg clearance and mobility
- Optimized access to the radio
- Easier maintenance access
- Enhanced HVAC ventilation

Air System

- Direct drive air compressor
- Wabtec FastBrake™ Locomotive Brake System
 - Advanced onboard diagnostics
 - FastBrake™ intelligence integrated into EM2000 and Gen2 FIRE™
 - Simpler FastBrake™ design allows for 50% reduction in parts count

OPTIONAL PERFORMANCE FEATURES

- [IntelliTrain](#) - Remote monitoring and analysis
- [Radial truck](#)
- Integrated Distributed Power
- Global Positioning System (GPS)
- Electronic fuel gauge with or without dynamic AEI tags
- Remote download of event recorder

Figure 25: EMD SD70Ace Locomotive Spec Sheet

4.0 Applicable Rules, Regulations, and Practices

The requirements established by the regulatory agencies and the Standards and Practices followed by the industry are typically specified in the technical documents of a vehicle procurement process.

4.1 *Federal Railroad Administration*

Any rail vehicle operating on tracks of the General System of Railways must be designed and built in full accordance with the Rules and Regulations established by the Federal Railroad Administration and codified in 49 CFR, Part 238. Part 239 also contains requirements for emergency preparedness and certain maintenance activities. FRA is the keeper and enforcer of these Regulations.

Under certain specific scenarios, FRA may allow operation of non-compliant vehicles, as discussed earlier. However, these potential waivers may become more difficult to obtain if the number of requests increase.

4.2 *American Public Transportation Association*

APTA adopted the old Recommended Practices previously maintained by the Association of American Railroads and further developed it under the Passenger Rail Equipment Safety Standards. APTA, with the participation of all commuter rail agencies and Amtrak, is now responsible for the update and maintenance of the Recommended Practices. All passenger rail operators on main line railroad tracks have embraced the Standards. Further, they are committed to include them as a mandatory requirement in their respective procurement specifications.

4.3 *Environmental Protection Agency*

The Environmental Protection Agency is responsible for establishing requirements for noise and exhaust emissions for transportation vehicles. Most relevant are the exhaust emission regulations applying to diesel engines, as used by locomotives and diesel rail cars.

4.4 *Association of American Railroads, Industry Standards and Practices, and Others*

While the Association of American Railroads is no longer maintaining Standards or Recommended Practices for passenger equipment, a number of standards common to other equipment remain under their control. Although not mandatory, these Standards are relevant and are typically included as requirements on any procurement process.

In addition, there are also relevant Standards and practices recommended by other organizations such as the American Society of Mechanical Engineers, Institute of Electrical, and Electronic Engineers, American National Standards Institute, etc.

5.0 Technology Trends

Technology trends for rail vehicles are further advanced in European and East Asian countries, where most of the research and application continues to evolve. As these technologies are demonstrated and proven, their respective performance eventually becomes the focus of attention of U.S. engineers. When appropriate, some level of research is then conducted, primarily for the purpose of integrating such technologies into the U.S. environment and ensuring consistency with relevant U.S. Standards and Practices.

5.1 *New Technologies for Conventional Systems*

There is continuous progress in the development of new technologies for application in passenger equipment. While many of these developments would contribute to better performance and efficiencies, others are creating safer vehicles. A typical example is the new crash energy management (CEM) features now being implemented on Metrolink cars for commuter services in southern California.

The industry is generally cautious about application of new technologies, which are typically tested and proven in revenue service, before full production implementation.

With regard to compliance with existing rules and regulations, it can be safely assumed that they will not change dramatically over the next few years. One area that perhaps may require further attention from the rule makers is CEM, discussed earlier. In this particular case, it is envisioned that better integration between current car-body strength requirements and CEM features would be further developed.

Technologies ready or soon to be ready for implementation are, among others:

- Information systems for security purposes and vehicle health monitoring;
- Electronic systems for controls;
- Fuel management systems;
- Suspension systems for safer and improved ride;
- Boarding access, combined with station platforms;
- Better, safer gangways (passageway between cars);
- Safer control cabs and systems;
- Lighter materials; and
- Hotel power generation for diesel-electric locomotives and rail diesel cars.

These and many other technologies will continue to evolve, creating safer and more efficient rail vehicles. The industry must remain alert, supporting research and development activities and application of new technologies in an orderly manner.

5.2 *New Arrangements*

Flexibility of operation is a critical factor in providing safe and efficient passenger rail services, as well as for maintenance of equipment. As new services are planned, ridership demand and trip time

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requirements have an impact on the arrangement of the rolling stock equipment and its ability to meet duty cycles, while increasing availability.

Along these lines, it is important to consider if, for instance, mid-day services would require a shorter train, in which case one must decide if the train consists should allow for daily changes or different equipment should be used.

Articulated trains are another arrangement gaining popularity, given that weight is well within the allowable axle loads. This arrangement also has the benefit of reducing the number of trucks and its corresponding maintenance.

The packaging of propulsion equipment is also an important consideration, given strict requirements for floor height, clearance envelopes, and serviceability.

5.3 Train Consists

The formation of trains is also dependant on market demand, length of station platforms, maintenance facilities, and energy consumption among other factors. It is therefore extremely important that the selection of equipment is consistent with such needs and requirements, while providing certain flexibility as conditions change.

5.4 High-Speed Rail

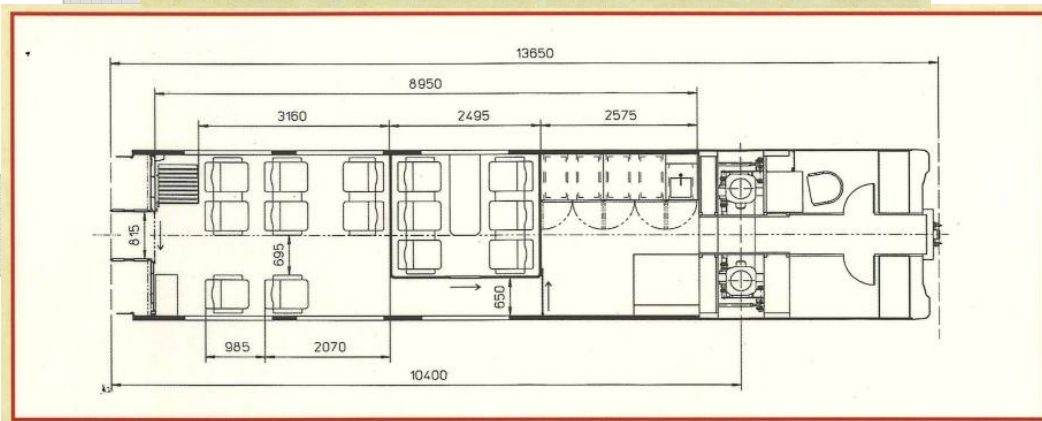
With regard to high-speed rail, the only application currently in operation in the United States is Acela Express, a 150 mph technology developed jointly by Bombardier and Alstom. A unique feature of this technology is its tilting mechanism, allowing the train to negotiate curves at higher speed without affecting comfort to the passengers. High-speed rail is under the jurisdiction of FRA, but governed by distinctive set of rules, depending on maximum operating speed, as follows:

- **Tier II** – These Rules apply to trains operating at speeds between 126 and 150 mph. The Acela train was designed and built during the development of the new FRA Rules, but research during the process was used to finalize the final requirements, later codified in 49 CFR, Part 238. This particular technology, capable of speeds up to 150 mph is governed by the FRA Rules known as Tier II.
- **Rules of Particular Applicability** – Beyond Tiers I and II Rules covering passenger rail equipment, any guided transportation mode operating at speeds above 150 mph, including rail and maglev guided technologies, fall under the Rules of Particular Applicability. This means that each particular case and each particular component of the system, such as vehicles, tracks and control systems, are evaluated individually and as a total system.

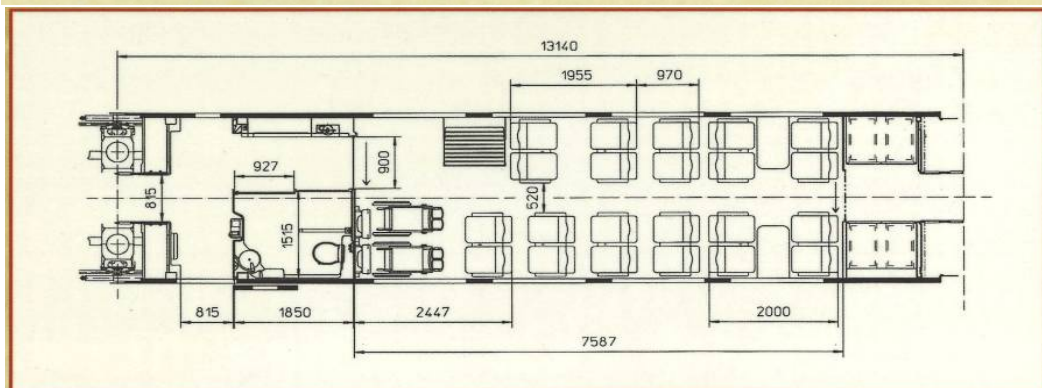
The Spanish Talgo equipment is rather unique in the North American market for high-speed rail service. Five train sets are currently being used in the Pacific Northwest, covering services between Portland, OR and Vancouver, BC. Talgo equipment is not compliant with applicable U.S. rules, regulations and standards, therefore is operating under a waiver awarded by the FRA.

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Talgo equipment (Figure 26) has gained popularity with passengers, providing a smooth and comfortable ride on existing tracks. Given its short overall length, about half of a conventional U.S. car, Talgo equipment may not be optimum for commuter services.



CLUB CLASS END CAR



COACH CLASS FOR WHEELCHAIR-BOUND PASSENGERS

Figure 26: Talgo Equipment

6.0 Fleet Size

Table 1 provides an overview of the fleet size requirements for three future Regional Rail Scenarios: Baseline, Alternative 1, and Alternative 2. The Baseline scenario includes services that are currently funded for implementation before 2030. Alternative 1 includes an expanded set of services and improved capacity and operating speeds, with heavy investment in the BART system. Alternative 2 includes an expanded set of services and still further investment in capacity and operating speeds above Alternative 1, but with modest investment in the BART system.

The fleet size calculations are based on the frequency of service in the peak direction of travel during the peak period. A minimum 5-minute layover at the end of each run was assumed, and 15 to 20 percent was added to account for spares. The number of railcars was also determined based on 5-car consists for major lines, 3-car consists for intermediate lines, and 2-car consists for minor lines.

7.0 Summary and Conclusions

As discussed, there are several modern technologies currently available and under development, serving the needs of commuter rail services around the world. These technologies are not always available or applicable in the United States, primarily because of incompatible rules and regulations and other operating conditions and protocols described in this report.

At present, availability of modern technologies is also limited, in part, by lack of electrification. If electrification is available, motive power could be provided by electric locomotives or electric-multiple units. However, through-running services that would operate on both electrified and non-electrified track segments would require a hybrid solution. Under either configuration, bi-level and single level passenger rail cars are available and must be evaluated in the context of market demand and other factors.

A further consideration is the issue of procurement, as the cost of rail equipment is related closely to the size of vehicle orders. While one equipment technology may be more suited to operating a particular service than another, procurement and ongoing maintenance costs would escalate with each different vehicle or technology. A regional rail fleet that is standardized as much as possible would minimize procurement costs, provide for redundancy in operations, and simplify maintenance procedures.

Table 2 includes a Summary of Rail Equipment in the Bay Area, both now and in the future. The future needs take into consideration the applicable rules and regulations, along with regional rail system integration and compatibility.

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Table 1: Projected Fleet Size Requirements

CORRIDOR / LINE	Baseline			Alternative 1			Alternative 2		
	Peak Headway	Trains Req'd	Cars Req'd	Peak Headway	Trains Req'd	Cars Req'd	Peak Headway	Trains Req'd	Cars Req'd
US-101 North Corridor									
Cloverdale <-> Larkspur	30	12	24	20	23	46	30	12	24
Santa Rosa <-> Stockton	-	-	-	-	-	-	60	8	16
North Bay Corridors									
San Rafael <-> Fairfield/Vacaville	-	-	-	60	4	8	30	9	18
Saint Helena <-> Vallejo Ferry	-	-	-	60	4	8	30	8	16
I-80 / East Bay / I-880 Corridor									
Sacramento <-> San Jose	-	-	-	30	18	90	-	-	-
Auburn <-> San Jose	90	8	24	60	10	30	-	-	-
Oakland <-> San Jose	-	-	-	-	-	-	30	6	30
Sacramento <-> Jack London Square	60	8	40	-	-	-	-	-	-
Peninsula Corridor									
San Francisco <-> Gilroy	60	8	24	-	-	-	-	-	-
San Francisco <-> San Jose	60	10	50	-	-	-	-	-	-
San Francisco <-> San Jose (express)	60	4	20	-	-	-	-	-	-
Salinas <-> SF 4th & Townsend (local)	-	-	-	40	13	39	-	-	-
Salinas <-> SF Transbay Terminal (local)	-	-	-	25	29	87	-	-	-
San Jose <-> SF 4th & Townsend (express)	-	-	-	40	5	25	-	-	-
San Jose <-> SF Transbay Terminal (express)	-	-	-	25	10	50	-	-	-
Hollister <-> San Francisco (local)	-	-	-	-	-	-	30	16	48
San Jose <-> Auburn (local)	-	-	-	-	-	-	30	28	84
San Jose <-> Sacramento (express)	-	-	-	-	-	-	15	53	265
South Counties Corridors									
Santa Cruz <-> Monterey	-	-	-	60	6	12	30	15	30
Gilroy <-> Hollister	-	-	-	60	2	4	-	-	-
Gilroy <-> Salinas	-	-	-	-	-	-	60	3	6
Transbay Corridors									
Merced <-> San Francisco	-	-	-	-	-	-	60	9	45
Union City <-> Millbrae	30	8	24	30	8	24	-	-	-
Union City <-> San Jose	30	9	27	30	9	27	60	4	12
West Oakland <-> San Jose	-	-	-	-	-	-	60	4	12
Central Valley Corridors									
Merced <-> Jack London Square via Stockton	-	-	-	90	6	12	-	-	-
Merced <-> Jack London Square via UPRR	-	-	-	60	10	50	-	-	-
Merced <-> Sacramento via UPRR	-	-	-	60	9	45	60	8	40
Tri-Valley Corridor									
Stockton -> San Jose	30	19	95	-	-	-	-	-	-
Sacramento <-> San Jose	-	-	-	30	25	125	-	-	-
Sacramento <-> Hollister	-	-	-	-	-	-	30	23	115

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Table 2: Summary of Rail Equipment in the Bay Area

Services	Type	Power	Seated Capacity per Car	Regulations and Standards	Compliant Equipment
Existing Services and Equipment					
BART	Heavy Rail	Electric	80	N/A	N/A
Caltrain	Commuter	Trailer/Cab	140	FRA	Yes
		Diesel Locomotive	N/A	FRA	Yes
ACE	Commuter	Trailer/Cab	140	FRA	Yes
		Diesel Locomotive	N/A	FRA	Yes
Capitol Corridor	Intercity	Trailer/Cab	90	FRA	Yes
		Diesel Locomotive	N/A	FRA	Yes
San Joaquins	Intercity	Trailer/Cab	90	FRA	Yes
		Diesel Locomotive	N/A	FRA	Yes
BNSF/UP	Freight	Diesel	N/A	FRA/AAR	Yes
Proposed Services and Equipment in Longer-term					
BART	Heavy Rail	Electric	80	N/A	N/A
eBART	Commuter	DMU	65	FRA	No
Caltrain	Commuter	EMU	145	FRA	No
Dumbarton	Commuter	Trailer/Cab or EMU	140-145	FRA	Yes or No
		Dual-Powered Locomotive	N/A	FRA	Yes
ACE	Commuter	Trailer/Cab	140	FRA	Yes
		Diesel Locomotive	N/A	FRA	Yes
Capitol Corridor	Intercity	Trailer/Cab	90	FRA	Yes
		Diesel Locomotive	N/A	FRA	Yes
SMART	Commuter	DMU	65	FRA	Yes
San Joaquins	Intercity	Trailer/Cab	90	FRA	Yes
		Diesel Locomotive	N/A	FRA	Yes
BNSF/UP	Freight	Diesel	N/A	FRA/AAR	Yes